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Multifunction Impulse Radiating Antennas: Theory and Experiment

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13. ABSTRACT *(Maximum 200 Words)*
A Multifunction Impulse Radiating Antenna (IRA) is an extension of a standard IRA that has the additional flexibility of an adjustable beamwidth. This ajustability is implemented by defocusing the feed to select between a narrow or broad beam. We provide the theory of operation of the antenna, for both in-focus and out-of-focus situations. Furthermore, we built and tested a design with a 46 cm diameter. We found reasonable agreement of the experiment with theory, although some work remains to be done in refining the feed point.

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I. Introduction

A reflector Impulse Radiating Antenna (IRA) consists of a parabolic reflector with a Transverse Electro Magnetic (TEM) feed. This class of antenna has a considerable body of literature associated with both its analysis and measurements [1-3]. One issue that has been raised concerning this type of antenna, however, is that the beamwidth is too narrow for many applications. To broaden the beam, we introduce the Multifunction IRA (MIRA).

The principle behind the MIRA is quite simple. The feed point of an IRA is normally at the geometric focus of a parabolic reflector. In an MIRA, we defocus the feed arms slightly by placing the feed point somewhat closer to the dish than its normal position at the focus of the reflector.

If one can add a mechanical control to the feed point location, then one can have a single antenna with a narrow or broad beam, as required. This results in a single antenna with very broad bandwidth and beamwidth control. Such an antenna may be useful in applications where a single antenna must serve multiple functions due to limited aperture space. In this note, we develop the theory of such a device, and we describe the fabrication and testing of a prototype design.

An experimental prototype was developed with a 46 cm (18 in) diameter reflector using four feed arms with an adjustable position. The position is controlled by a servo mechanism that is controlled by a personal computer.

By including computer control in the design, we allow a great deal of flexibility in system design. One might use the MIRA as part of a radar system that can operate in either search mode, that requires a broad beamwidth, or tracking mode, that requires a narrow beamwidth. A block diagram of such an arrangement is shown in Figure 1.1. The controller would select which of two radar systems would be fed into the antenna. The controller would also set the antenna feed position to control the beamwidth.

The field is measured using TEM sensors. These were developed based on an idea by C.J. Buchenauer [4] to enhance signal-to-noise ratio with very fast, low-voltage pulsers. These sensors are replicating sensors, not the derivative sensors that are perhaps more commonly used. We calibrate these sensors using two identical sensors.

The material in this report is a shortened version of [5]. The reader is referred to that reference for additional detail.

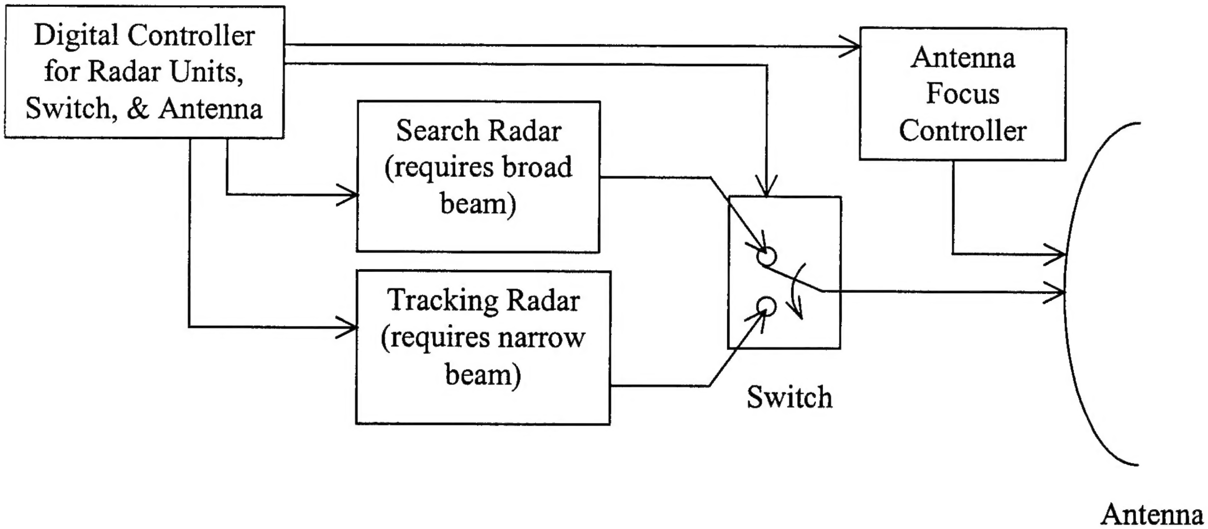

Figure 1.1. Control of the RF switch and antenna focus using a digital controller.

II. Experimental Setup and Measurements

A diagram of the Multifunction IRA built for this project is shown in Figure 2.1. It includes a solid 18-in diameter parabolic reflector that slides along a set of four fixed feed arms. A servo motor controls the position of the reflector with respect to the feed, and a laptop computer communicates with the servo controller using a serial port.

During the Phase I project it was also necessary to develop sensors that could be used to measure the radiated field. Standard derivative-type sensors have a very low sensitivity, so any measurements we made with our 4-V sources would have been very noisy. Thus, we decided to develop a replicating sensor, which would replicate the incident electric field from the boresight direction. The design was essentially a half TEM horn mounted against a truncated ground plane (Figure 2.2). Data showed the sensor successfully replicated the field for about the first two nanoseconds.

The experimental test configuration for the Phase I measurements is shown in Figure 2.3. In includes a Picosecond Pulse Labs 4015C step generator, which drives a TEM sensor. On the receive end, the Multifunction IRA receives the signal, which is then sampled by the SD24 sampling head and the Tektronix 11801B Digital Sampling Oscilloscope (DSO). Data is then downloaded to a computer for processing by way of a GPIB connection.

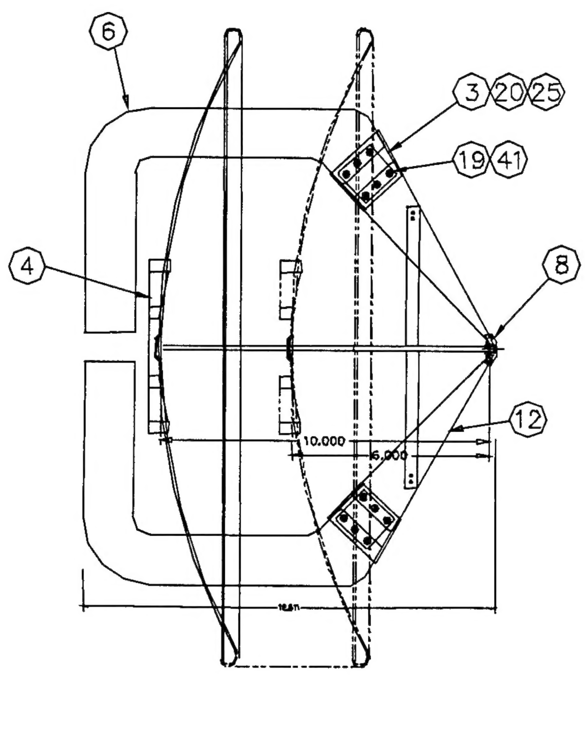

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Figure 2.1. The Phase I Multifunction IRA.

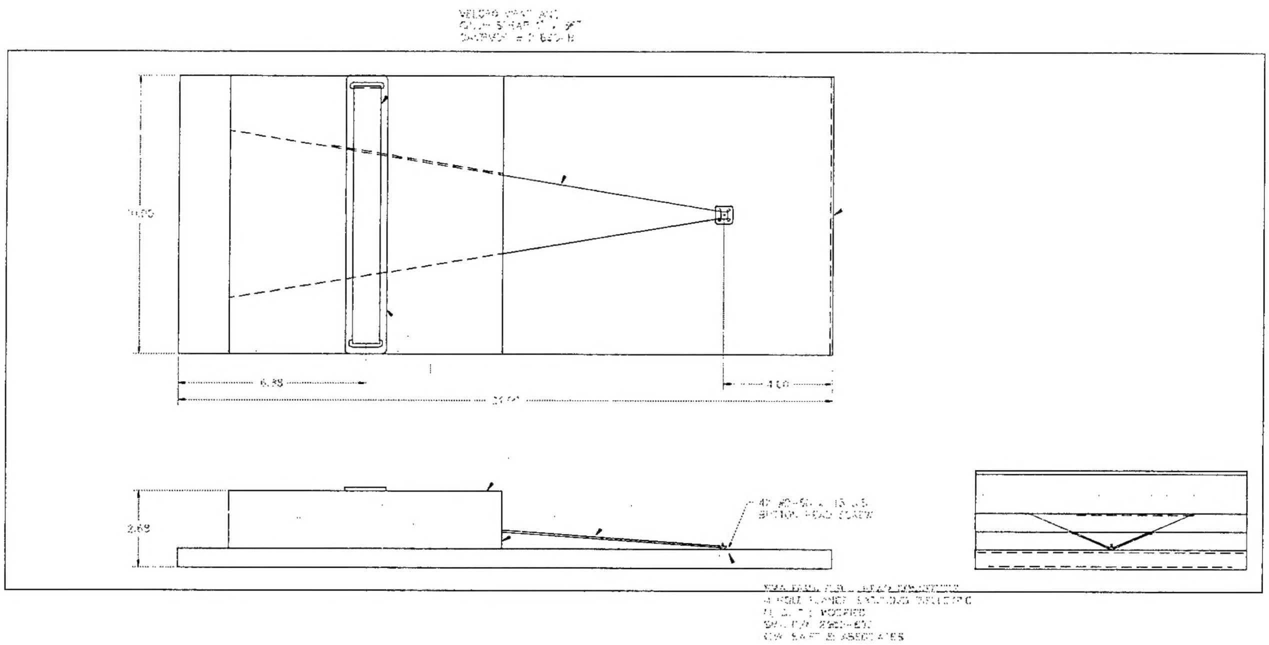

Figure 2.2. TEM Sensor

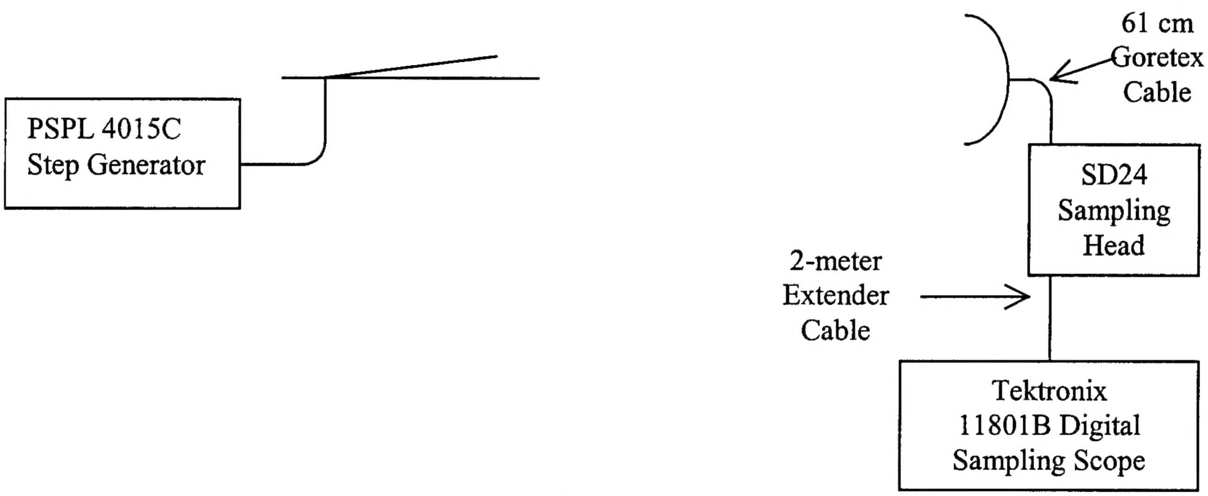

Figure 2.3. Experimental test setup

The boresight response for the Multifunction IRA (MIRA) is shown in Figure 2.4. It displays the classic time-domain waveform of a low-level prepulse, followed by a sharp impulse, with Full Width Half Max of 60 ps. The impulse has a shoulder formation, or a second impulse of a smaller magnitude. This can also be seen in the frequency response (Figure 2.5), which shows a dip near 5 GHz. This feature is due to some features that improved mechanical stability. Because of these features, the antenna has been made very sturdy, at some expense to electrical performance. It will be necessary to trade off mechanical and electrical properties in later versions of this antenna.

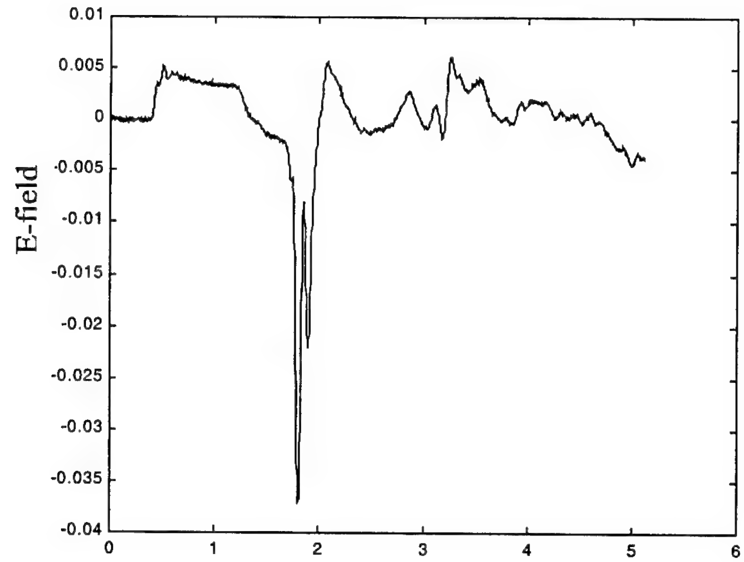

Figure 2.4. Boresight step response of the Multifunction IRA.

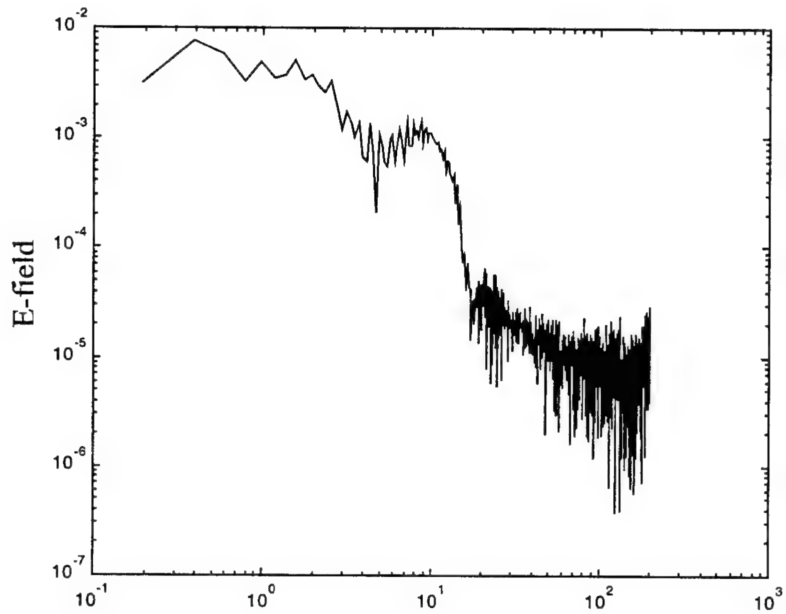

Figure 2.5. Frequency response of the Multifunction IRA.

Next, we consider the antenna pattern as a function of angle off-boresight, and as a function of focus. Recall that the purpose of the adjustable focus on this antenna is to be able to control the beamwidth by controlling the focus. To measure this, we measure three different radiated waveforms, at 0, 7.5, and 15 degrees off boresight in the H-plane, and we do this for

three different focus positions, *F*, .85*F*, and .7*F*. In our terminology, the focus position is the distance from the antenna feed point to then reflector, measured in units of the focal length of the reflector. So when the focus position is *F*, the antenna is in focus. When the focus position are set at .85*F* and .7*F*, the antenna becomes progressively more out of focus.

The patterns for dish settings of *F*, 0.85 *F* and 0.7 *F* are shown in the top, middle, and bottom of Figure 2.6, respectively. From this data, we can estimate the half-angle beamwidths in the three configurations as 7.5, 12, and 15 degrees, for focal positions of *F*, .85*F* and .7*F*, respectively. Thus, the antenna is operating as expected, with the beam width increasing as the antenna becomes more out of focus. Note that the definition of the beamwidth of a time domain waveform is a matter of some debate.

Finally, we note that it was necessary to calibrate the TEM sensors, in order to complete the experiment. This was accomplished by using two identical TEM sensors, and processing the data to obtain a response for the single antenna. The result is shown in Figure 2.7. This is a very clean impulse, with FWHM = 33 ps. Thus, our measurement system provides a good replication of the incident field, with a smearing of only 33 ps, which is quite good for this measurement.

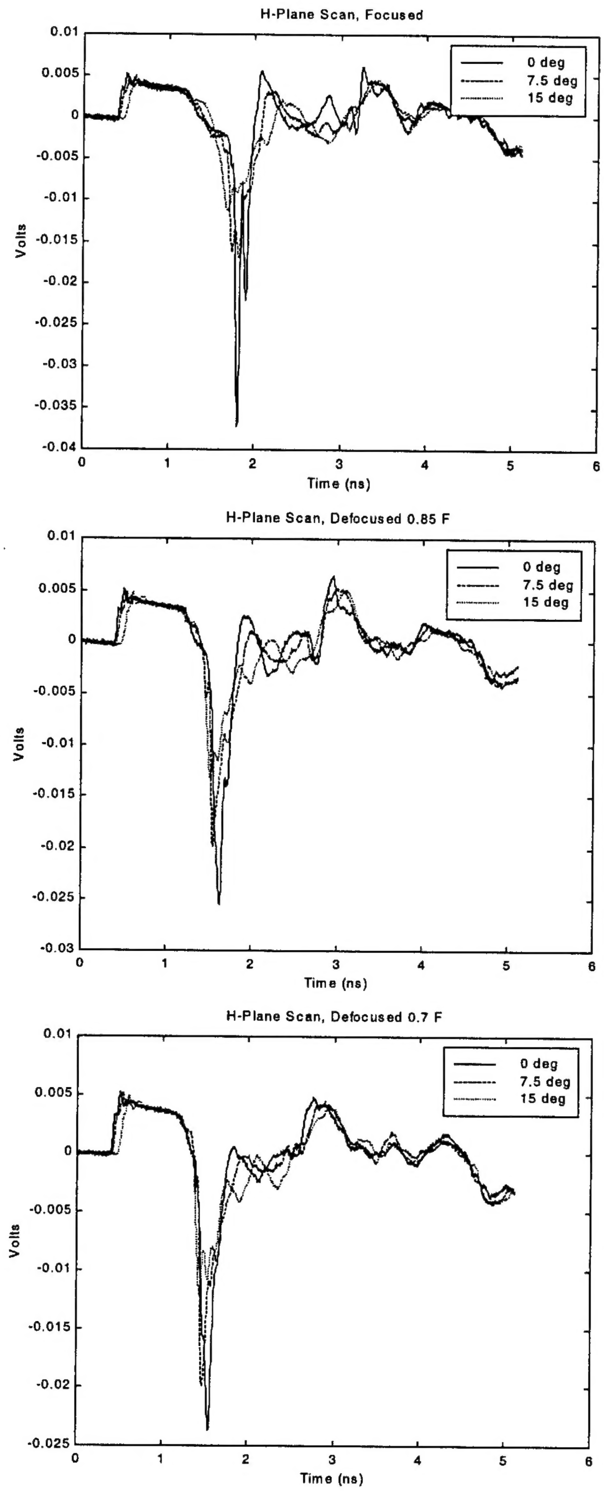

Figure 2.6. Antenna response for MIRA with focus set at F (top), .85F (middle), and .7F (bottom). Antenna responses are for 0, 7.5, and 15 degrees off boresight.

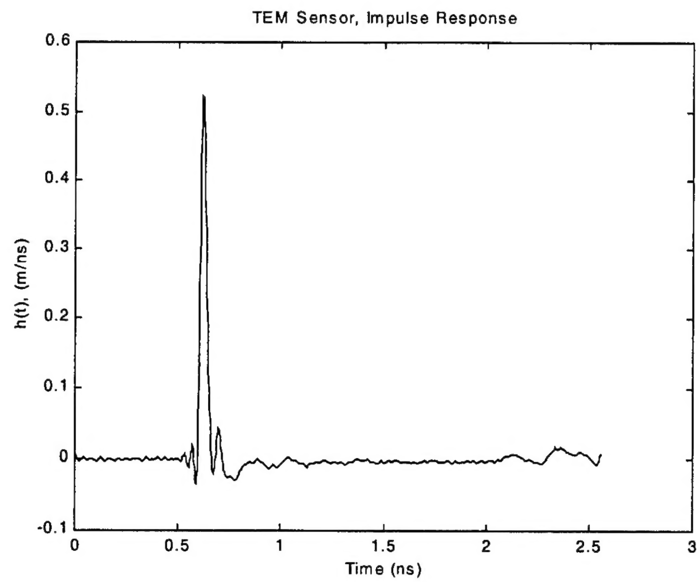

Figure 2.7. Step response of TEM sensor in transmission.

III. Conclusions

We have built and tested an MIRA with a 46 cm diameter. Satisfactory agreement was obtained between theory and measurements, although refinements will be necessary. These refinements include a better impedance match at the MIRA apex. It will also be necessary to take more data at greater distances, to verify that it is taken in the far field.

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5. E. G Farr, C. E. Baum, and W. D. Prather, Multifunction Impulse Radiating Antennas: Theory and Experiment, Sensor and Simulation Note 413, November 1997.

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